PRAMANA — journal of physics

Vol. 69, No. 5
November 2007
pp. 943–946

Results from GRACE/SUSY at one-loop

J FUJIMOTO[1], T ISHIKAWA[1], M JIMBO[2], T KANEKO[3],
T KON[3], Y KURIHARA[1], M KURODA[4], Y SHIMIZU[5] and Y YASUI[2,*]
[1]KEK, Oho, Tsukuba, Ibaraki 305-0801, Japan
[2]Tokyo Management College, Ichikawa, Chiba 272-0001, Japan
[3]Seikei University, Musashino, Tokyo 180-8633, Japan
[4]Meiji Gakuin University, Totsuka, Yokohama 244-8539, Japan
[5]The Graduate University for Advanced Studies, Hayama, Kanagawa 240-0193, Japan
[*]E-mail: yasui@tmc-ipd.ac.jp

Abstract. We report the recent development on the SUSY calculations with the help of GRACE system. GRACE/SUSY/1LOOP is the computer code which can generate Feynman diagrams in the MSSM automatically and compute one-loop amplitudes in the numerical way. We present new results of various two-body decay widths and chargino pair production at ILC (international linear collider) at one-loop level.

Keywords. Radiative corrections; supersymmetry.

PACS Nos 02.70.-c; 11.15.Bt; 12.38.Bx; 12.60.Jv

1. Introduction

The supersymmetric (SUSY) theories are the prime candidates for the high energy particle physics beyond the standard model. The SUSY model is well motivated which was proposed as a solution of the hierarchy problem. Since the spectrum of the SUSY particles depends on the scenario of the model at higher energy scale, such as the GUT and the Planck scale, the detailed information of the SUSY parameters at the TeV scale may provide a probe to understand the nature of the early Universe.

Since we require that ILC has not only the capability to discover new physics, but also the potential to measure mass parameters and couplings precisely, precision measurements of the SUSY parameters will be one of the important issues at ILC experiment. We are to determine the mass parameters and couplings for SUSY particles within a few per cent precision [1]. To realize such precision measurements, in the theoretical side, the estimation of radiative corrections (RC) is essential.

Many authors have already discussed the RC studies of SUSY models [3–6]. However, the calculations of the RC in SUSY models are highly nontrivial. SUSY models include a large number of particles and couplings. Thus, a vast number of Feynman diagrams appear in the loop calculation. Performing such computation

Table 1. One-loop electroweak corrections on decay widths.

	Parent's mass (GeV)	Γ_0 (GeV)	$\delta\Gamma/\Gamma_0$ (%)
$H^0 \to d\bar{d}$	431.4	2.75×10^{-4}	+18
$H^0 \to b\bar{b}$	431.4	1.80	+9.7
$H^+ \to t\bar{b}$	438.4	1.45	+4.7
$H^+ \to \nu_\tau \tau^+$	438.4	8.75×10^{-2}	+16
$H^+ \to \tilde{\chi}_1^0 \tilde{\chi}_1^+$	438.4	1.21×10^{-1}	+4.0
$\tilde{e}_1^- \to e^- \tilde{\chi}_1^0$	123.2	7.80×10^{-2}	+7.8
$\tilde{\chi}_1^+ \to \nu_\tau \tilde{\tau}_1^+$	184.2	2.93×10^{-2}	+9.0
$\tilde{\chi}_2^+ \to Z^0 \tilde{\chi}_1^+$	421.1	7.53×10^{-1}	−2.8
$\tilde{\chi}_3^0 \to W^- \tilde{\chi}_1^+$	405.2	1.47	−4.2
$\tilde{\chi}_3^0 \to Z^0 \tilde{\chi}_1^0$	405.2	4.42×10^{-1}	+2.5
$\tilde{t}_1 \to b\tilde{\chi}_1^+$	347.4	1.35×10^{-1}	+13
$\tilde{t}_1 \to t\tilde{\chi}_1^0$	347.4	1.28×10^{-1}	+7.5
$\tilde{b}_1 \to t\tilde{\chi}_1^-$	469.4	1.22	+5.5
$\tilde{b}_1 \to b\tilde{\chi}_1^0$	469.4	1.65×10^{-1}	−1.4
$\tilde{u}_1 \to u\tilde{\chi}_1^0$	506.5	9.61×10^{-1}	+8.1

is absolutely beyond the human power if it should be done by hand. Since the procedure of a perturbation calculation is well established, computers must be able to take the place of human hand. In this decade, several groups have developed computer programs which generate Feynman diagrams and calculate cross-sections in the MSSM, like GRACE/SUSY [7,8], FeynArts-FormCalc [9] and CompHEP [10].

In this talk, we report the recent developments of the new system named GRACE/SUSY/1LOOP. This system, the upgraded version of GRACE/SUSY, can calculate full one-loop Feynman amplitudes in the minimal supersymmetric extension of the standard model (MSSM). In the next section, we show the results of the one-loop calculations for various two-body decay processes and the chargino pair production at e^+e^- colliders.

2. Physical results

To demonstrate the loop calculations, we adopt the gauge symmetric and on-shell renormalization scheme of the MSSM [11]. For the consistency check of the numerical results, we introduced the nonlinear gauge (NLG) fixing terms. This technique is the analogy of the NLG check which was used in the non-SUSY calculations with the GRACE/LOOP system [12]. We also tested the consistency checks of the ultraviolet finiteness and the infrared finiteness. All of these numerical tests have been done in the quadruple precision. Throughout the calculation we use the SPA1a' parameter sets [13].

First, we show the one-loop radiative corrections for various two-body decay widths of the Higgs and sparticles in table 1. We notice that the electroweak corrections $\delta\Gamma/\Gamma_0$ for the processes whose decay products include leptons are of the

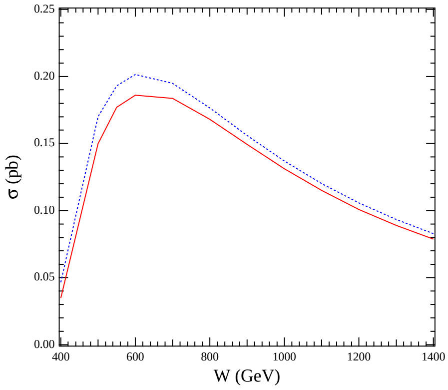

Figure 1. Total cross-section for chargino pair production. Solid and dotted lines denote $\sigma_{\rm elwk}$ and $\sigma_{\rm BORN}$, respectively.

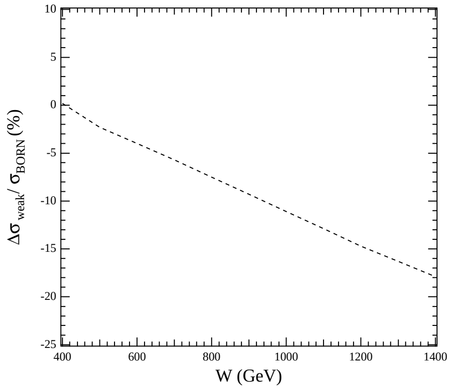

Figure 2. Weak correction for chargino pair production.

order of +10–+15%. For the processes where the Higgs or the gauginos decays into two heavy particles (weak gauge bosons or gauginos), $\delta\Gamma/\Gamma_0 \simeq -5$–$+5\%$. As for squarks decays, $\delta\Gamma/\Gamma_0$ sensitively depends on the masses and the mixing angles in the squark sector.

The next example is the one-loop calculation of the lighter chargino pair production at e^+e^- colliders. We show the energy dependence of the total cross-section in figure 1, where $W = \sqrt{s}$ and

$$\sigma_{\rm elwk} = \sigma_{\rm BORN}(1 + \delta_{\rm 1loop} + \delta_{\rm soft}) + \sigma_{\rm hard}. \tag{1}$$

The one-loop electroweak correction is of the order of −10%. We note that RC of this order can be detectable at the proposed ILC.

The RC on the chargino pair production in the SPA1a' scenario has already been studied by the Wien group [5]. Unfortunately, since they adopt different treatment of the photon emission correction, the direct comparison of our result with theirs is not possible. In figure 2 we show the energy dependence of the 'weak' correction $\Delta\sigma_{\rm weak}/\sigma_{\rm BORN}$ defined by

$$\Delta\sigma_{\rm weak} \equiv \sigma_{\rm elwk} - \sigma_{\rm BORN} * \delta_{\rm QED} - \sigma_{\rm hard}^{\rm initial}. \tag{2}$$

We find that our result is consistent with the values presented in [5]. From figure 2, we find that the weak correction becomes non-negligible, of the order of −5% for $\sqrt{s} = 600$ GeV.

3. Summary

GRACE/SUSY/1LOOP is the automatic computation system which can calculate full one-loop amplitudes for up to 2→2 processes in MSSM. Using this system, we demonstrated the systematic studies of several two-body decay widths at one-loop level and also estimated the radiative corrections for the chargino-pair production at ILC. The GRACE/SUSY/1LOOP system works successfully and the results of the radiative corrections are as sizable as the order of 5–15%. We expect that the GRACE/SUSY/1LOOP will be a powerful tool of the data analysis for the precision measurement at ILC.

Acknowledgements

This work was supported in part by the Japan Society for Promotion of Science (JSPS) under the Grant-in-Aid for Scientific Research B (No. 17340085 and No. 17540283) and by the International Research Group on Automatic Computational Particle Physics (IRG ACPP) funded by CNRS/Universities in France, KEK in Japan and MSU/RAS/MFBR in Russia.

References

[1] See for example: K Abe *et al*, GLC Project, KEK Report 2003-7 (2003)
[2] H P Nilles, *Phys. Rep.* **110**, 1 (1984)
H E Haber and G L Kane, *Phys. Rep.* **117**, 75 (1985)
[3] T Fritzsche and W Hollik, *Euro. Phys. J.* **C24**, 619 (2002); *Nucl. Phys. Proc. Suppl.* **135**, 102 (2004)
T Blank and W Hollik, hep-ph/0011092
W Hollik and H Rzehak, *Euro. Phys. J.* **C32**, 127 (2003)
A Arhrib and W Hollik, *J. High Energy Phys.* **0404**, 073 (2004)
J Guasch, W Hollik and J Sola, hep-ph/0307011
[4] H Eberl, W Majerotto and Y Yamada, *Phys. Lett.* **B597**, 275 (2004)
H Eberl, M Kincel, W Majerotto and Y Yamada, *Nucl. Phys.* **B625**, 372 (2002)
K Kovarik, C Weber, H Eberl and W Majerotto, *Phys. Lett.* **B591**, 242 (2004)
[5] W Öller, H Eberl and W Majerotto, *Phys. Rev.* **D71**, 115002 (2005)
[6] A Freitas and D J Miller, *eConf*, **C010630**, E3061 (2001)
[7] J Fujimoto *et al*, *Comput. Phys. Commun.* **111**, 185 (1998)
[8] J Fujimoto *et al*, *Comput. Phys. Commun.* **153**, 106 (2003); Program package GRACE/SUSY (GRACE v2.2.0) is available from http://minami-home.kek.jp/
[9] T Hahn, *Nucl. Phys. Proc. Suppl.* **89**, 231 (2000)
T Hahn, *Comput. Phys. Commun.* **140**, 418 (2001)
T Hahn and C Schappacher, *Comput. Phys. Commun.* **143**, 54 (2002)
[10] D S Gorbunov and A V Semenov, hep-ph/0111291.
A Semenov, *Nucl. Instrum. Methods* **A502**, 558 (2003)
[11] M Kuroda, in Research report to the Ministry of Education, Science and Culture, Japan, the Grant-in-Aid for Scientific Research C (No. 08640391) (1999) 127
[12] G Bélanger, F Boudjema, J Fujimoto, T Ishikawa, T Kaneko, K Kato and Y Shimizu, *Phys. Rep.* **430(3)**, 117 (2006)
[13] J A Aguilar-Saavedra *et al*, *Euro. Phys. J.* **C46**, 43 (2006)